INFLUENCE OF SPRAY VOLUMES, NOZZLE TYPES AND ADJUVANTS ON THE CONTROL OF PHOMA COFFEE RUST

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(Recebido: 05 de setembro de 2016; aceito: 08 de março de 2017)

ABSTRACT: Pesticides are often applied under incorrect conditions such as inappropriate nozzles types and high spray volumes. Such errors result in spray drift and run off, causing inefficiency on the control of pests and diseases, beyond environmental contamination. Here we evaluate the influence of spray volumes, nozzle types and adjuvants on the control of phoma and coffee rust. The objective in this work was to evaluate the feasibility of reducing the volume of syrup in the absence and presence of adjuvant, using three spray nozzle types, analyzing the uniformity of the spray distribution to thirds of the plant and its penetration and effectiveness of phytosanitary products. The treatments were t arranged in a factorial 3 x 2 x 2 + 1, outlined in a randomized block design with three replications in a split plot. Treatments were three-pointed on type empty cone (ATR Amarela; JA Preto e Disc-Core AD2AC23), two spray volumes (300 and 500 L ha^{-1}), on absence and presence of adjuvant (TRUMP), and a control (experiment without disease control). It was concluded that the volume of spray liquid can be reduced to 300 L ha^{-1}, without harming the quality of spraying and disease control. The adjuvant has not brought any benefits for the application, and the most suitable spray nozzle is the ATR Amarela.

Index terms: Pesticide application technology, crop protection products, coverage of droplets, spraying quality.

INFLUÊNCIA DOS VOLUMES DE PULVERIZAÇÃO, TIPOS DE PONTA E ADJUVANTES SOBRE O CONTROLE DA PHOMA DE CAFÉ

RESUMO: *O controle fitossanitário do cafeeiro muitas vezes é realizado em condições incorretas como utilização de pontas inadequadas no pulverizador e volume de calda excessivo. Tais erros resultam em deriva, escorrimento superficial provocando a ineficiência do controle de pragas e doenças, além de contaminação ambiental. Objetivou-se por meio deste trabalho avaliar a viabilidade de se reduzir o volume de calda, na ausência e presença de adjuvante, utilizando três pontas de pulverização, analisando a uniformidade de distribuição da calda nos terços da planta, bem como sua penetração e a eficácia de produtos fitossanitários. Os tratamentos foram dispostos no esquema fatorial 3 x 2 x 2 + 1, delineados em blocos casualizados, com três repetições, em parcelas subsubdivididas. Os tratamentos foram três pontas do tipo cone vazio (ATR Amarela; JA Preto e Disc e Core AD2AC23), dois volumes de calda (300 e 500 L ha^{-1}), e ausência e presença de adjuvante (TRUMP), além de uma testemunha sem controle de doenças. Concluiu-se que o volume de calda pode ser reduzido para 300 L ha^{-1}, sem prejudicar a qualidade de pulverização e o controle de doenças. O adjuvante não trouxe benefícios à aplicação. A ponta mais indicada é a ATR Amarela.*

Termos para indexação: *Tecnologia de aplicação de defensivos, defensivos, área de cobertura, qualidade da aplicação.*

1 INTRODUCTION

After the mechanical process of harvest, coffee plants are more susceptible to contracting diseases such as blight (*Hemileia vastatrix*), phoma / ascochyta (*Phoma* sp.), gray leaf spot (*Cescospora coffeicola*), among others (MATIELLO et al., 2010). Mainly because this, there is a long period without treatment with pesticides and also damages caused by harvest operations (SANTINATO et al., 2014). Furthermore, the period of post-harvest may be favorable to the occurrence of diseases due natural increases of moisture during this period. In addition, this period coincides with the pre-bloom period, and the common concern of producers is to protect what will eventually be its production (FERNANDES; FERREIRA; OLIVEIRA, 2010; MATIELLO et al., 2010).

Although pesticides provides proved control for major diseases, unsatisfactory results on coffee crops occurs due to the pesticide application method used. Another point is the waste of pesticides which can vary 15-70% (COSTA et al., 2008). The growers adopt high spray volumes that promote waste of pesticides by spray drift (ALVES; CUNHA, 2014) and run off through the leaves.

Some factors that affect the quality of the application can be defined before the application, such as droplet size and application volume (DI

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OLIVEIRA; FERREIRA; ROMÁN, 2010). The droplet size is determined through the use of different types of nozzles, the operating pressure and the formulation of products which may or may not have the addition of adjuvants. Therefore, the selection of nozzles is very important, justifying performing studies in order to define appropriate nozzles for different and specific application conditions (BUENO; CUNHA; ROMAN, 2013).

The application quality may be substantially enhanced with the use of specific adjuvants (IOST; RAETANO, 2010). Adjuvants should be used specifically for each type of pesticide to be applied appropriately to modify the surface properties of the liquid such as surface tension and vapor pressure (MONTÓRIO et al., 2005).

Here we evaluate the influence of spray volumes, nozzle types and adjuvants on the control of phoma and coffee rust.

2 MATERIAL AND METHODS

The study was conducted at Fazenda Toca da Raposa, in the county of Carmo do Paranaíba, MG, Brazil. The experimental area corresponds to 4.0 ha, with an average gradient of 5%. The crop was planted in 1997 using Catuaí Vermelho IAC 144 with the spacing of 4.0 m between lines and 0.5 m between plants (5,000 plants ha^{-1}). The plants had an average height of about 4.0m and 70% leafiness.

The experimental design was randomized blocks in factorial 3 x 2 x 2 + 1 (13 treatments), and split plots. Treatments were three-pointed cone empty type (ATR yellow; JA Black e Disc-Core AD2AC23), two spray volumes (300 and 500 L ha^{-1}), changed according to the operating speed of the tractor, and the absence and presence of siliconized adjuvant (TRUMP). Such nozzles are frequently used in the cerrado region of Minas Gerais State. Also was used a treatment control with pesticide application aimed to verify the incidence of pests and diseases (rust, gray leaf spot and *phoma* / *ascochyta* complex).

The split plot and sub split plot design were the thirds of the plant (top and bottom) and the depth of collection (external and internal). There were three replicates, totaling 39 plots, each with 50 plants. For each treatment were used three lines of coffee about 200 m, and the central useful for evaluations and the adjacent, for borders.

The sprayer used was Arbus 2,000, Jacto company, trailed, hydropneumatic, arched, with capacity tank to 2,000 L. The machine was equipped with 24 hydraulic nozzles, twelve on each side, with the nozzles of the upper and lower ends 0.6 and 1.8 m high from the ground. Working pressures was alternated between 5,0 and 7,0 bar. The sprayer was pulled by a tractor Massey Ferguson model MF 265, 4 x 2 TDA, with nominal power of 47.8 kW (65 hp) operating at variable speeds as the treatments under study.

The applications (October to December 2013) had used the fungicide Boscalid (Cantus) at a dose of 180 g ha^{-1}, Pyraclostrobina (Comet) at a dose of 400 ml ha^{-1} and Epoxyconazole + Pyraclostrobina (Opera) at a dose of 1.0 L ha^{-1}. According to each pesticide labels.

Before spraying the treatments evaluation of diseases incidence was held. The presence is recorded from symptoms of diseases in 50 sheets of each plot in the first and second pairs (phoma / ascochyta) and third and fourth pairs (other diseases). The values were transformed in percentage and had an incidence of 3.0; 6.5 and 1.0% for rust, gray leaf spot and *phoma / ascochyta* respectively. Such an assessment was repeated 60 days after each of the two applications in order to verify the effectiveness of the products according to the study treatments.

The evaluation of the implementation of quality was consisted in parameters of density and coverage of droplets. Twelve water sensitive papers (26 x 76 mm) were used on three plants per plot, four out of the plant. The water sensitive papers were arranged in the upper and lower third of canopy plants, internally and externally (position). Was adopted the upper third and lower as the height equivalent to 70% of plant and 30, respectively. Was adopted external and internal position as been the 4th pair of sheets (outside to inside) and the trunk of the plant, respectively.

After the treatments, the water sensitive papers were removed (using gloves to preserve the coverage data and kept on dry case). At lab it was analyzed by scanning each paper using CIR1.5 software with resolution of 600 DPI. The data were submitted to variance analysis and when appropriate Tukey's test, both at 5% probability.

3 RESULTS AND DISCUSSION

The spray volume of 300 L ha^{-1}without adjuvant, using ATR nozzles types, shown highest density of droplets (Table 1). In the presence of adjuvant, the ATR nozzles and Disc and Core AD2AC23 had obtained the highest densities.

TABLE 1 - Density droplets (droplets per cm^{-2}) in the edge function, spray volume, and absence or presence of adjuvant.

Nozzles	Spray volume (L ha^{-1}) 300 Adjuvant Presence	300 Absence	500 Presence	500 Absence
ATR Yellow	402,6 aA1	473,8 aA2	305,6 bB1	399,2 aB2
JA Black	269,8 bA1	381,9 bA2	306,2 bA1	415,3 aA2
Disc-Core AD2AC23	400,3 aA2	330,9 bB1	420,5 aA1	452,6 aA1
CV (%)	33,73			

* Lower case letters compare each nozzle in volume of spray liquid and adjuvant. Capital letters compare each volume within nozzle and adjuvant. The numbers compared the adjuvant within the edge and the volume. Mean followed by the same lowercase, in columns and uppercase letters, in the rows, or letters do not differ by the Tukey test at 5% probability.

In the higher spray volume without adjuvant, there was no difference between nozzles. Using adjuvant, Disc and Core nozzles had the highest density droplets, among those tested, without however differ from the absence of product. That is, the addition of adjuvant was beneficial to Disc and Core nozzles, in particular situation, and not positively influenced the density drops for ATR and JA nozzles. Thus, using adjuvant can be an interesting strategy to increase the density drops for some nozzles.

When comparing spray volumes with each nozzle, was noted that ATR nozzles obtained higher density drops when used 300 L ha^{-1}, by using or not adjuvant. Then, it is mean that spray volume can change the density of droplets for ATR nozzles. Related with others nozzles, there was no differences between both spray volumes tested independently of adjuvant use. Thus, reducing spray volume from 500 to 300 L ha^{-1}does not decrease the density of droplets. Those results are positive mainly because droplets provide by higher density generally has lower drift (SILVA; CUNHA; NOMELINI, 2014).

And this is positive because, drops of higher density generally have lower drift (SILVA; CUNHA; NOMELINI, 2014).

Using small spray volumes, independently of mixture adjuvant in the spray solution, ATR nozzle got greater coverage area (Table 2). For higher spray volume, also independently of mixture adjuvant, there was no difference between nozzles. But when added to the product, the JA nozzle showed high coverage. The use of adjuvant did not reflect differences for ATR nozzle, on the highest and lowest spray volumes. The JA nozzle was better without adjuvant than with, in the lower volume. Also, no difference between the absence and the presence of the product on the higher tested volume. There was no difference between the use of adjuvant for Disc and Core in both volumes tested. Thus, it confirms the previous discussion, relating to the droplet density, that the addition of an adjuvant may be beneficial for some types of nozzles.

There was no difference in coverage between tested spray volumes using ATR nozzle in the presence of adjuvant. In the absence of adjuvant, area coverage was better with 300 than 500 L ha^{-1}.

For JA nozzles using adjuvant, was higher thecoverage on the higher spray volume. Such nozzle, in the absence of adjuvant, did not differ between 300 and 500 L ha^{-1}. The nozzle Disc and Core regardless of the adjuvant and the spray volume also displayed no difference in the coverage area. Despite the increase in Spray coverage in plants to be directly proportional to the increase in application volume (FERREIRA; LEITE; LASMAR, 2013), this work demonstrates the feasibility of reducing spray volume for the three tested nozzles, with no loss in coverage. Using smaller spray volume may contribute to reducing drift (RAMOS et al., 2004).

Both the upper third as the lower, the ATR nozzle achieved the highest densities droplets for 300 L h^{-1} (Table 3). The application reached two-thirds of the plant without suffering density changes, even with a large distance between the thirds, because it is plant 4.0 m tall. This was also observed for the others nozzles.

TABLE 2 - Coverage area (%) at peak function, spray volume, and absence or presence of adjuvant.

Nozzles	Spray volume (L ha^{-1})			
	300		500	
	Adjuvant			
	Presence	Absence	Presence	Absence
ATR Yellow	14,6 aA1	16,8 aA1	12,9 abA1	12,5 aB1
JA Black	8,0 bB1	14,3 abA2	13,5 aA1	13,9 aA1
Disc-Core AD2AC23	11,3 abA1	13,3 bA1	10,1 bA1	12,4 aA1
CV (%)	46,54			

* Lower case letters compare each nozzle in volume of spray liquid and adjuvant. Capital letters compare each volume within nozzle and adjuvant. The numbers compared the adjuvant within the edge and the volume. Mean followed by the same lowercase, in columns and uppercase letters, in the rows, or letters do not differ by the Tukey test at 5% probability.

TABLE 3 - Density of drops (drops cm^{-2}) in function of the nozzle, volume of spray liquid at the upper and lower thirds of the plant.

Nozzles	Spray volumes (L ha^{-1})			
	300		500	
	Thirds of the plant			
	Upper	Lower	Upper	Lower
ATR Yellow	409,2 aA1	467,2 aA1	346,6 aB1	358,2 bB1
JA Black	312,1 bA1	339,8 bA1	351,7 aA1	369,8 bA1
Disc-Core AD2AC23	370,2 abA1	361,1 bB1	414,6 aA1	458,6 aA1
CV (%)	34,39			

* Lower case letters compare each nozzle in volume of spray liquid and adjuvant. Capital letters compare each volume within nozzle and adjuvant. The numbers compared the adjuvant within the edge and the volume. Mean followed by the same lowercase, in columns and uppercase letters, in the rows, or letters do not differ by the Tukey test at 5% probability.

On two-thirds evaluated, there was obtained the higher coverage using ATR nozzles with 300 L ha^{-1}, comparing with other nozzles (table 4). On the highest volume, there was no difference between nozzles in the lower third. Nevertheless the upper third, using JA nozzle high coverage was found. Increased coverage of droplets on top of coffee plants was also observed by Miranda et al. (2012). Theses authors also evaluated high spray volumes. Thus, it can understand that higher volumes may result in uneven distribution of application.

The ATR nozzles had the highest density of droplets on the outside and inside of the coffee plants, using 300 L ha^{-1} than the others nozzles (Table 5). The nozzle Disc-Corespraying 500 L ha^{-1} had the highest density on the inside, while on the outside there was no difference between the nozzles.

Inside the plant, the JA nozzles showed off highest density with 500 than 300 L ha^{-1}. On the outside, the JA and also Disc-Core did not differ between both spray volumes tested. However, the ATR nozzles results higher densities with the low spray volume, both externally and internally. There was no difference between the outer and inner depth in any of the situations. Except using Disc-Core with 500 L ha^{-1} when density was higher in the inner depth.

The ATR nozzles got the most coverage with 300 L ha^{-1} at both depths, than the others nozzles (Table 6). In the higher spray volume there was no difference between nozzles on the outside depth. With this volume the JA nozzle, had the highest coverage in the inner depth of the plants.

The volume of 300 L ha^{-1} was sufficient to promote adequate penetration of the droplets for all nozzles, with no difference between the two depths. In the higher spray volume. Disc Core nozzles got more coverage on the inner depth than the outside depth.

TABLE 4 - Coverage area (%) due nozzles, spray volumes at upper and lower thirds of the coffee plants.

Nozzles	Spray volume (L ha^{-1})			
	300		500	
	Thirds of the plant			
	Upper	Upper	Upper	Upper
ATR Yellow	15,2 aA1	16,1 aA1	11,7 bB1	13,8 aA1
JA Black	11,5 bB1	10,8 bB1	15,5 aA1	13,9 aA1
Disc-Core AD2AC23	12,7 abA1	11,9 bA1	11,4 bA1	11,1 aA1
CV (%)	47,41			

* Lower case letters compare each nozzle in volume of spray liquid and adjuvant. Capital letters compare each volume within nozzle and adjuvant. The numbers compared the adjuvant within the edge and the volume. Mean followed by the same lowercase, in columns and uppercase letters, in the rows, or letters do not differ by the Tukey test at 5% probability.

TABLE 5 - Density droplets (droplets per cm^{-2}) due nozzles, spray volumes at the upper and lower thirds of the coffee plant

Nozzles	Spray volume (L ha^{-1})			
	300		500	
	Depth			
	Inner	Outer	Inner	Outer
ATR Yellow	433,4 aA1	442,9 aA1	362,8 bB1	341,9 aB1
JA Black	318,6 bB1	333,2 bA1	349,1 bA1	372,3 aA1
Disc-Core AD2AC23	349,6 bA1	381,6 abA1	498,8 aA2	374,4 aA1
CV (%)	34,38			

* Lower case letters compare each nozzle in volume of spray liquid and adjuvant. Capital letters compare each volume within nozzle and adjuvant. Numbers compared adjuvant inside edge and volume. Average followed by the same lowercase, uppercase or letters do not differ by Tukey test at 5% probability.

TABLE 6 - Coverage area (%) in function of the nozzles, spray volumes at the upper and lower thirds of the plant.

Nozzles	Volume os syrup (L ha^{-1})			
	500		300	
	Depth			
	Inner	Outer	Inner	Outer
ATR Yellow	16,11 aA1	15,2 aA1	13,4 aA1	12,1 bB1
JA Black	10,7 bA1	11,6 bB1	13,4 aA1	16,1 aA1
Disc-Core AD2AC23	12,3 bA1	12,3 abA1	12,6 aA2	9,8 bA1
CV(%)	47,33			

* Lower case letters compare each nozzle in volume of spray liquid and adjuvant. Capital letters compare each volume within nozzle and adjuvant. The numbers compared the adjuvant within the edge and the volume. Mean followed by the same lowercase, in columns and uppercase letters, in the rows, or letters do not differ by the Tukey test at 5% probability.

In general, applications had good penetration of droplets, showed by equal coverage in external and internal depths. This occurred with all the nozzles tested.

Hence, hollow cone nozzles were more suitable for pesticide applications aimed to crops when great penetration of droplets are needed (DECARO JÚNIOR et al., 2014; MIRANDA et al., 2012), as coffee plants. This shows the importance of selecting appropriate nozzles (MADALOSSO et al., 2010) because they are directly related to the quality of the operation, influencing the droplet size, the distribution of sprayed liquid and uniform pattern distribution of droplets (SASAKI et al., 2013).

Regardless to nozzle types, spray volumes, and absence or presence of adjuvant, was noted the effectiveness of the product boscalid, Epoxyconazole Pyraclostrobina was high, getting incidence values lower than the control (Figure 1). This fact enables the reduction of spray volume for 300 L ha^{-1}, for using less water in the tank, raises the capacity over all work of the operation, in addition to saving this natural resource. As in the experiment was obtained average of 12.97% coverage area, this proves efficient for the control of diseases, using the tested products.

4 CONCLUSIONS

Based on the results found in this study, using spray volume of 300 L ha^{-1} and hollow cones (better results for ATR nozzles) ensures a good control of phoma and coffee rust, and the use of adjuvants in the spray mixture may be indifferent to spraying process.

Syrup volume in pesticide applications in the coffee can be reduced to 300 L ha^{-1} and does not impair the control of diseases.

The nozzle most appropriate among those studied for applications in the coffee is the ATR Yellow.

The use of adjuvants does not alter the density drops and application coverage area.

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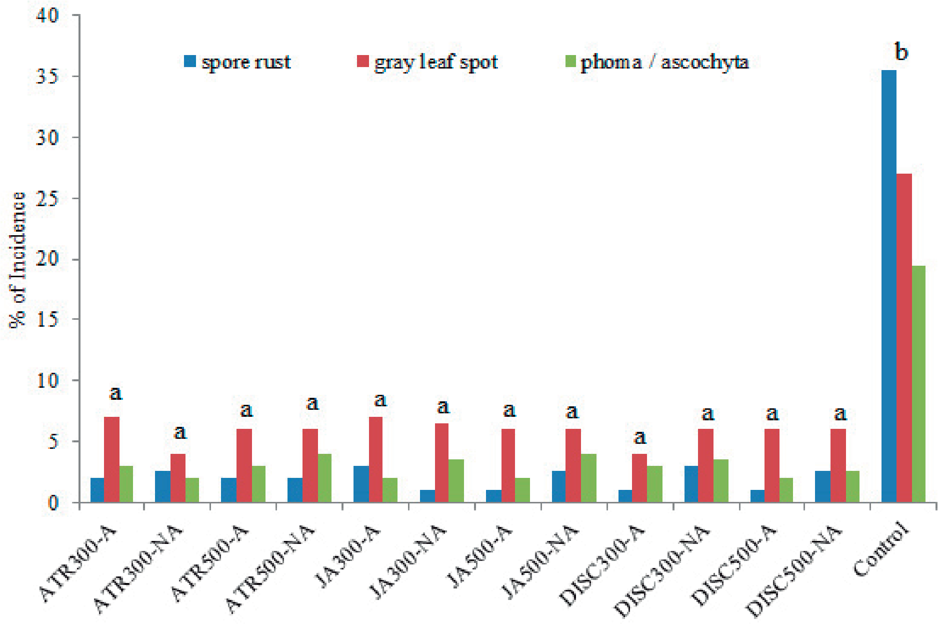

FIGURE 1 - Incidence of spore rust, gray leaf spot and phoma / ascochyta in coffee, 60 days after the last application, in function of nozzles, spray liquid volume and absence and presence of adjuvant. A- With adjuvant, NA-No adjuvant, Control-No chemical control.

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